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ADDITIONAL NOTES ON CHLORITE

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Since the publication of the writer's discussion[1] of "Chlorite as a Polycomponent System," a monograph on the composition of chlorite[2] has appeared from the pen of Dr. J. Orcel of the Paris Museum of Natural History. This monumental work is so much more complete than any previous study of the chlorite system that our knowledge of the subject has been increased to an extraordinary extent. For example, all previous work on chlorite furnished only eighteen examples of samples on which optic data were measured on material known to be the same as that which was analyzed, and more than half of these are unsatisfactory because of impure material or for other reasons. Orcel gives eighteen new analyses of chlorite made by modern methods on material very carefully purified and accompanied by optic data in each case. It is obviously important and almost necessary to make use only of analyses of samples whose purity has been demonstrated by microscopic study in order to make real progress in understanding the composition of complex silicates such as chlorite. It is only because such analyses have been very uncommon that others have been used in previous attempts to unravel the problems of the constitution of chlorite. Orcel has added very largely to the stock of new analyses of chlorite of *known purity*, and he has fortunately supplied optic data for nearly all the samples analyzed. Therefore it is desirable to study again the constitution of chlorite and the relations between composition and optic properties.

One chapter of Orcel's monograph, occupying fifty pages, is devoted to a study of the water in chlorites, and particularly to phenomena attending dehydration of various samples of chlorite. Orcel has applied the double galvanometer of Saladin-Le Chatelier to obtain a photographic record of very slight thermal changes in many samples of pure chlorite, including some as different in composition as possible. From this study he reached the extremely important conclusion that Tschermak's theory of the constitution of chlorite is probably incorrect.[3] This conclusion is based on the fact that the thermal curves of clinochlorite, ripidolite, penninite, etc., are not like those of antigorite and amesite nor intermediate between them (in character). Such evidence is not at all convincing to the writer especially in view of the fact that the thermal curves obtained by the same method by Orcel on different samples of one kind of chlorite (for example, grochauite, or leuchtenbergite, or ripidolite) differ nearly as much from one another as those of antigorite and of amesite differ from those of clinochlorite and the other intermediate chlorites.

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[1] *Am. Jour. Sci.*, **CCXI**, 1926, pp. 283–300.

[2] Recherches sur la Composition Chimiques des Chlorites: *Bull. Soc. Min. Fr.*, **L**, pp. 75–456, 1927; also issued as doctor's thesis No. **1958** (A 1,108) of Univ. Paris, 1927.

It seemed possible that the new method of studying crystal structure by means of X-ray patterns might throw some light on this question of the relationships between amesite, penninite, antigorite, etc.; consequently patterns were obtained from the following minerals:—

1. Antigorite, Antigorio Valley, Piedmont.
2. Penninite, Viesch, Switzerland.
3. Clinochlorite.
4. Corundophilite, Chester, Mass.
5. Amesite, Chester, Mass.
6. Prochlorite, Vermont.
7. Aphrosiderite, Michigamme, Michigan.
8. Thuringite.

The results, shown in Fig. 1, are not conclusive. The X-ray pattern of antigorite is much simpler than that from any other mineral of the series, a condition which corresponds well with its simpler composition. It has one well-defined line which does not correspond with any line of the aluminous chlorites and is therefore not easily understood. However, it seems to be true that various types of aluminous chlorites differ from one another in their X-ray patterns as much as they differ from antigorite—aside from the simplicity of the latter. It will require a detailed and perhaps prolonged study of these patterns to obtain final results from them.

Although Orcel rejects the theory of Tschermak as improbable, his own classification recognizes a *continuous variation* in composi-

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[3] *Op. cit.*, p. 288 and 322.

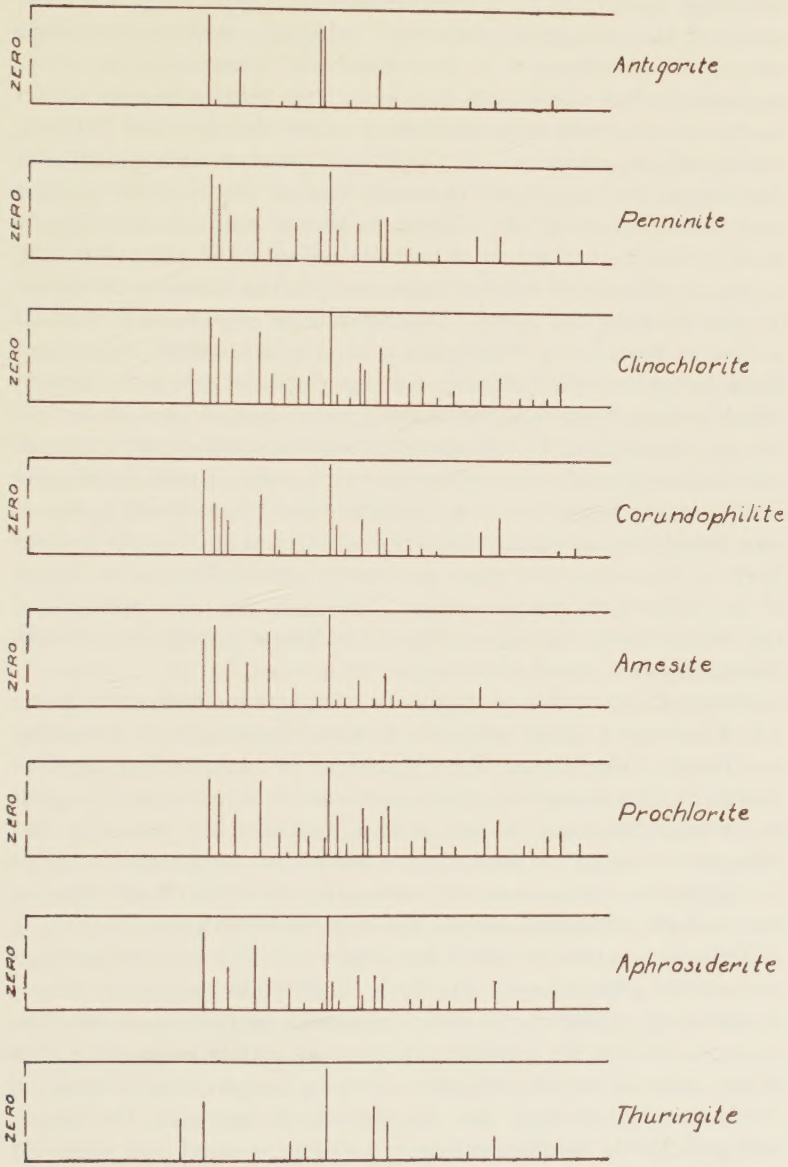

Figure 1. X-ray patterns of antigorite, penninite, clinochlorite, corundophilite, amesite, prochlorite, aphrosiderite and thuringite. The length of each line is proportional to its estimated intensity.

tion from amesite to more than 60 per cent. (apparently to 80 per cent.) of the antigorite molecule.[4] In any such isomorphous series which is admitted to be continuous, it seems to the writer undesirable and misleading to dignify any definite simple (intermediate) ratio with a special name. Any simple ratio between albite and anorthite in the plagioclase series is exceptional and due merely to chance, and the same kind of statement is true for any isomorphous series. When a simple ratio is the normal result of the natural forces of chemical affinity and crystallization, as in the case of the ratios expressed in the formula of albite, it deserves a special name. When a simple ratio is only a result of chance there is no better reason to give it a special name than there is, for example, to create a series of special names for liquids which consist of mutual solutions of water and alcohol in various simple proportions. If an isomorphous series is sufficiently common and different in its component parts to make special names desirable for its parts, these names should not be supposed to represent simple ratios (which are exceptional), but definite continuous parts of the series, and these parts may well be limited by means of the exceptional simple ratios. These are the ideas which lead the writer to the conclusion that Orcel's new classification of the chlorite system is not acceptable.

It seems reasonable to divide an isomorphous series into parts which represent equal amounts of chemical variation. According to Orcel's classification the differences in composition increase markedly, but irregularly, from penninite to amesite, and there is much less difference in composition between his penninite and clinochlorite than between his corundophilite and amesite. This is doubtless a consequence of attempting to define these types in terms of the accidental simple ratios between SiO_2 and Al_2O_3.

The new analyses of Orcel have been made by modern methods on samples whose purity has been determined by careful microscopic study. They are therefore very much better than most of the analyses of chlorite published heretofore. It is interesting that these more accurate analyses serve to support the theory of Tschermak since they can be calculated into the Tschermak molecules with discrepancies which are very small and probably negligible in all cases except for those samples containing important amounts of ferric iron. This is substantially the same condition that was found (allowing larger discrepancies) in the older analyses. Increase in accuracy has resulted in a marked decrease in the discrepancies, exactly as it should if the theory of Tschermak is correct. It is very interesting to observe, also, that Orcel's analyses of chlorites rich in ferric iron do not fit the theory of Tschermak just as many of the older analyses of thuringite, etc., do not fit that theory. However, the new analyses can be made to correspond very well with Tschermak's theory by the same assumption made in regard to the older analyses, that is, that the iron has changed its state of oxidation (actually or apparently) in the chlorite after its formation. In the case of Orcel's analyses it is necessary to assume that the ferric iron has been produced in the chlorites by oxidation of ferrous iron. By assuming that all the ferric iron in all of Orcel's analyses represents oxidized ferrous iron, his analyses can be calculated into Tschermak's molecules with discrepancies which are negligible in all cases.[5] It is hoped that further attempts to change the state of oxidation of iron in chlorites experimentally may be undertaken soon.

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[4] Orcel expresses this variation not in terms of the amesite and antigorite molecules, but in terms of the $SiO_2:Al_2O_3$ ratio.

Summarizing the situation produced by the publication of Orcel's new data in regard to the chemical constitution of chlorites it seems to the writer that the evidence in favor of Tschermak's theory has been considerably strengthened and no changes are needed in the chemical interpretation previously presented.[6]

The situation is not the same with regard to the relations between optic properties and variations in chemical composition. Orcel's new data are much better in purity of samples and accuracy of correlation between optic and chemical data than were available before. In fact, if only those analyses be considered which are accompanied by optic data on the same material and which can be calculated into Tschermak's molecules with a maximum discrepancy (disregarding H_2O) of 1.5 per cent. of SiO_2 there were only six such analyses available before the publication of Orcel's monograph; he has added twice as many. Therefore it is now possible to revise the diagram showing the relations between optic properties and chemical composition and make it more accurate. The new data require only one important change in the diagram, namely, a more rapid increase in the mean index of refraction. It is very gratifying to find that the diagram needs almost no change so far as the optic sign and birefringence are concerned. The revised diagram[7] is given in Figure 2.

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[5] Disregarding H_2O and calculating so as to concentrate the discrepancies in SiO_2, the maximum discrepancy is 0.8 SiO_2.

[6] A. N. Winchell: *Am. Jour. Sci.*, CCXI, 1926, p. 283.

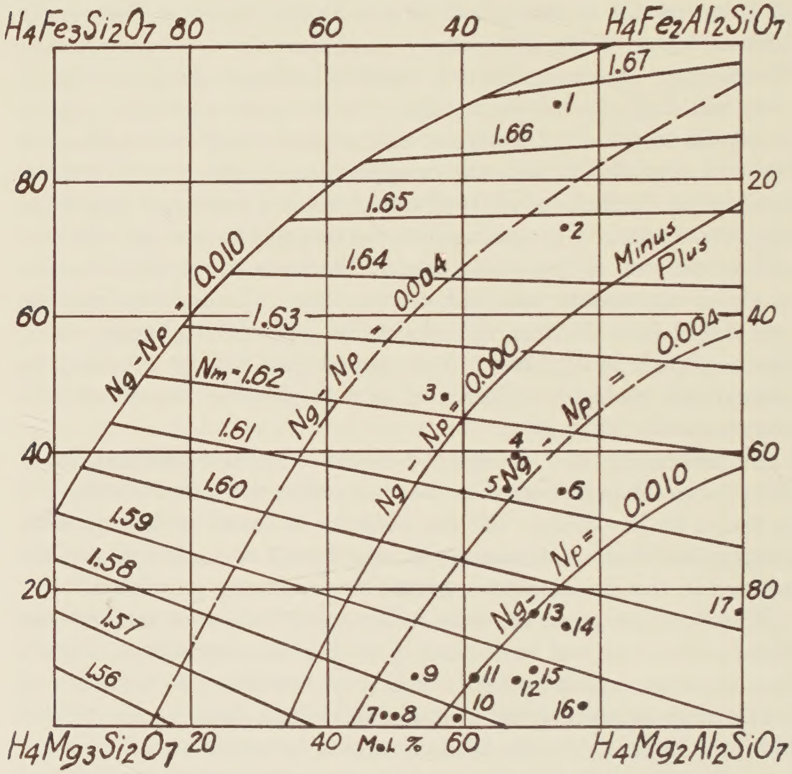

Figure 2. Relations between optic properties and chemical composition in the chlorite system.

It is obvious that this diagram makes it necessary to redefine the optic subdivisions of the chlorite system in order to make them correspond as nearly as possible with the chemical subdivisions. The new statement follows:—

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[7] It is an interesting fact that Jakob's "ekmannite" (*Schweiz. Min. Pet. Mit.*, IV, 1924, p. 51) which seems to be a manganiferous ferroantigorite fits the diagram very well in optic sign and mean birefringence, but has a birefringence of 0.048.

Optic Subdivisions of the Chlorite System

Name	Sign	N_m	N_g-N_p
Antigorite	−	1.55–1.58	0.004–0.010
Delessite	−	1.59–1.61	0.000–0.004
Jenkinsite	−	1.58–1.61	0.004–0.010
Diabantite	−	1.61–1.63	0.000–0.004
Aphrosiderite	−	1.63–1.65	0.000–0.004
Daphnite	−	1.65–1.68	0.000–0.004
Thuringite	−	1.65–1.68	0.004–0.010
Penninite	−	1.56–1.59	0.000–0.004
Penninite	+	1.57–1.61	0.000–0.004
Ripidolite	+	1.61–1.63	0.000–0.004
Clinochlorite	+	1.57–1.59	0.004–0.010
Prochlorite	+	1.59–1.62	0.004–0.010
Amesite	+	1.58–1.61	0.010–0.015±

In regard to the accuracy of Fig. 2 it may be noted that the points on the diagram are plotted from the analyses (list of references given later) and the diagram gives the mean index of refraction with a maximum error of 0.007; gives the birefringence with a maximum error of 0.005, except for No. 16 for which the error is 0.008; and gives the optic sign correctly in all cases.

The diagram in its revised form has been based entirely on the most accurate data available, but it is worthy of note that it gives the optic data with reasonable accuracy for many cases,[8] which have not been used because the optic measures were not made at the same time as the analyses and therefore were not *certainly* made on the same material that was analyzed, and also for the recent analyses of Shannon[9] and others for which material was too scanty to permit complete analyses.

In the writer's former study of chlorite[10] the conclusion was reached that some chlorite is isotropic and the evidence in support of this conclusion was summarized. Orcel considers the evidence insufficient to prove the point and presents a diagram (Fig. 15, p. 417) showing variations in composition in relation to variations in the mean index of refraction and the birefringence with a change in optic sign without passing through zero birefringence. His diagram is open to two criticisms. First, equal distances on the axis of abcissas do not represent equal differences of composition—on the contrary, the distance from zero to one represents more difference in composition than the entire remaining distance, one to ten; this is the main reason for the sharp curvature in the lines representing optic properties. Second, the diagram shows a change of sign without passing through zero birefringence, which is not

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[8] See especially the cases of chlorites analyzed by others and optically measured by Orcel.

[9] *U. S. Nat. Mus. Bull.*, **131**, 1926, p. 378.

[10] *Am. Jour. Sci.*, **CCXI**, 1926, p. 283.

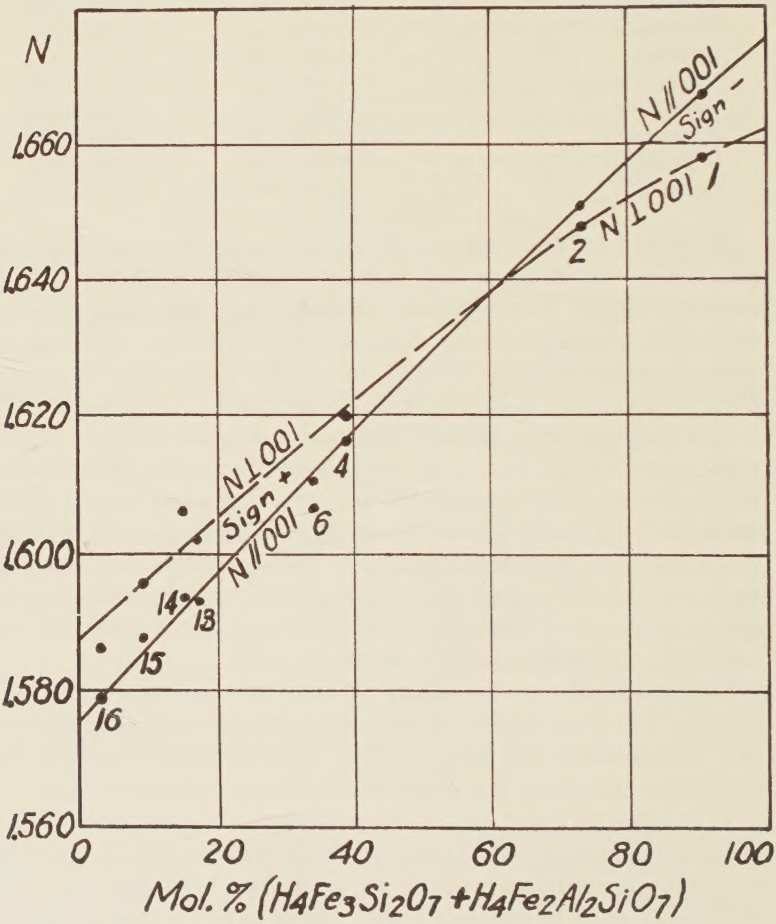

Figure 3. Relations between tenor of ferrous iron molecules and indices of refraction in chlorites contaning 68–78 per cent. of (amesite+daphnite). N_g is abnormally high in No. 14 probably on account of more Fe_2O_3 than in Nos. 13 and 15. The indices of No. 6 are a little too low, but the birefringence is about correct for the diagram.

correct for chlorite, as can be seen from a study of Fig. 3. The index of refraction for the direction normal to 001 is greater than that for directions parallel with 001 for chlorites with little ferrous iron; the difference decreases with increase of ferrous iron; finally, the index for the direction normal to 001 becomes less than that for directions parallel with 001 in chlorites with much ferrous iron. If it be admitted that physical properties in an isomorphous series vary continuously, then it is necessary that in this series of chlorites the two indices must be equal at some point, and chlorite of this type must be isotropic, at least for monochromatic light.

REFERENCES AND OPTIC DATA FOR FIGURES 2 AND 3.

1. "Bavalite," Bas-Vallon, France, J. Orcel: *Bull. Soc. Fr. Min.*, **L,** 1927, pp. 245–248; Orcel's analysis 128. $G.=3.20$, $(-)2V=$ very small. $N_g=N_m=1.667$ (calc. from N_g-N_p), $N_p=1.658$, $N_g-N_p=0.009$. $X=$ pale yellowish green, $Y=Z=$ olive-green.

2. "Aphrosiderite," Weilburg, Nassau. J. Orcel: *op. cit.*, pp. 251–253; Orcel's analysis 123. $(-)2V=?$ $N_g=N_m=1.651$, $N_p=1.648$, $N_g-N_p=0.003$ (calc.), 0.004 (obs.). $X=$ pale yellowish green, Y[11] $=Z=$ dark olive green. These data serve to correct the data of Larsen (*U. S. Geol. Surv. Bull.* **679,** 1921, p. 41) on unanalyzed "aphrosiderite" from the same locality. Sandburger (*N. Jahrb. Min.*, **1850,** p. 341) gives $G.=2.8$ for aphrosiderite of similar composition from the same locality.

3. Diabantite, Westfield, Mass. E. V. Shannon: *Proc. U. S. Nat. Mus.*, **LVII,** 1920, p. 397. $G.=2.77$. $(-)2V=0°\pm$. $N=1.62\pm$.

4. "Ripidolite," Isère, France. J. Orcel: *Op. cit.*, pp. 229–231; Orcel's analysis 95. $G.=2.90$. $(+)2V=$ very small. $N_g=1.620D$, $N_m=N_p=1.616$, $N_g-N_p=0.004$. $Z\wedge\perp 001=$ very small. Color olive green very weakly pleochroic with $X=Y>Z$.

5. "Ripidolite," Androta, Madagascar. J. Orcel: *Op. cit.*, pp. 227–229; Orcel's analysis 93. $G=2.883$ or 2.87. $(+)2V=0°$. $N_g=1.621$, $N_m=N_p=1.618$, $N_g-N_p=0.003$. $Z\wedge\perp 001=$ small. $X=Y=$ olive green, $Z=$ pale olive green.

6. "Prochlorite," Waterworks tunnel, D. C. Analysis by F. W. Clarke and E. A. Schneider: *U. S. Geol. Surv. Bull.* **78,** 1891, p. 19. Optic data by E. S. Larsen (*U. S. Geol. Surv. Bull.* **679,** 1920, p. 123): $(+)2V=$ small; $Z\perp$ 001; $N_m=1.605$, $N_g-N_p=$ weak. Optic data also by E. V. Shannon (*Proc. U. S. Nat. Mus.*, **LVII,** 1920, p. 475): $(+)2V=$ very small; $N_g=1.610$, $N_m=N_p=1.606$, $N_g-N_p=0.006$; $X=Y=$ deep blue-green, $Z=$ pale brownish green.

7. "Clinochlore," Togoland. J. Orcel: *Op. cit.*, pp. 267–270; Orcel's analysis 272. $G.=2.657$. $(+)2V=$ very small. $N_g=1.576$ (calc. from N_g-N_p), $N_m=N_p=1.571$, $N_g-N_p=0.0053$. Contains central zone with $N_g-N_p=0.003$. Common twinning on 001. Color green, not pleochroic.

8. "Chromiferous clinochlore," Togoland. J. Orcel: *Op. cit.*, pp. 267–270; Orcel's analysis 271. $G.=2.675$. $(+)=$ very small. $N_g=1.584$ (calc. from N_g-N_p), $N_m=N_p=1.579$, $N_g-N_p=0.005$. Contains central zone with $N_g-N_p=0.003$. Color violet or pink, not pleochroic.

[11] Orcel gives $X=Y$, which must be incorrect, unless the mineral is positive.

9. "Clinochlore," Besofotra, Madagascar. J. Orcel: *Op. cit.*, pp. 266–267; Orcel's analysis 170. $(+)2V=0°$ nearly. $N_g=1.594$ (calc. from N_g-N_p), $N_m=N_p=1.584$, $N_g-N_p=0.010$. $Z\wedge\perp 001=$small. Color green, not pleochroic.

10. "Leuchtenbergite," Midongy, Madagascar. J. Orcel: *Op. cit.*, pp. 195–199; Orcel's analysis 47. $G.=2.656$. $(+)2V=18°–19°$ Na. $N_g=1.5904$ Na, $N_m=1.5754$ (calc.) $N_p=1.5749$, $N_g-N_p=0.0155$. Colorless. $Z\wedge\perp 001=$very small.

11. "Prochlorite," Ambatofinandrahana, Madagascar. J. Orcel: *Op. cit.*, pp. 199–202; Orcel's analysis 71. $G.=2.713$. $(+)2V=29°$ *D*. $N_g=1.5989$, $N_m=1.5887$, $N_p=1.5880$, $N_g-N_p=0.0109$. Color green. $Z\wedge\perp 001=$small.

12. "Prochlorite," Carter mine, Madison Co., N. C. J. Orcel: *Op. cit.*, pp. 205–209; Orcel's analysis 57. $G.=2.696$. $(+)2V=19°$. $N_g=1.600$ (calc. from N_g-N_p as measured on another sample), N_m nearly$=N_p=1.588$, $N_g-N_p=0.012$ (measured on another sample).

13. "Prochlorite," Rainbow Camp, Leydsdorp, Transvaal. J. Orcel: *Op. cit.*, pp. 212–216; Orcel's analysis 68. $(+)2V=$small. $N_g=1.602$ (calc. from N_g-N_p), $N_m=N_p=1.593$, $N_g-N_p=0.009$. Color ashy green.

14. "Prochlorite," Antohidrano, Madagascar. J. Orcel: *Op. cit.*, pp. 217–220; Orcel's analysis 67. $G.=2.754$. $(+)2V=25°$; $N_g=1.606$ (calc. from N_g-N_p), $N_m=N_p=1.594$, $N_g-N_p=0.012$. Color green. A slightly different analysis is given by A. Lacroix: *Minéral. Madagascar*, **III**, 1923, p. 297, with $(+)2E=40°$, $N_g=1.595$, $N_m=1.592$, $N_p=1.584$—these indices require a negative sign.

15. "Prochlorite," Madison Co., N. C. J. Orcel: *Op. cit.*, pp. 205–209: Orcel's analysis 58. $G=2.718$. Optic data on p. 415: $N_g=1.596$, $N_m=N_p=1.588$, $N_g-N_p=0.008$. Optic data (and slightly different analysis) also given by Orcel in *Comp. Rend.*, **CLXXVI**, 1923, p. 1231, as follows: $(+)2V=19°$, $N_g=1.587$, $N_m=1.582$, $N_p=1.576$, $N_g-N_p=0.011$. (N_m must be about 1.578 if $2V$, N_g and N_p are correct).

16. "Sheridanite," Comberousse, Savoie, France. J. Orcel: *Op. cit.*, pp. 189–193; Orcel's analysis 31. $G.=2.680$. $(+)2V=12°\pm$Na. $N_g=1.586$ (calc. from N_g-N_p), $N_m=1.580$, $N_p=1.578$, $N_g-N_p=0.008$. Colorless spherulites. $Z\wedge\perp 001=$small.

17. "Amesite," Chester, Mass. E. V. Shannon: *Am. Jour. Sci.*, **CXCIX**, 1920, p. 96. Orcel's analysis 2. $G.=2.77$. $(+)2V=$very small. $N_g=1.612$, $N_m=N_p=1.597$, $N_g-N_p=0.015$ (calc.), 0.010 (observ.). Color green. $Z\wedge\perp 001=$very small.

LARGE MAGNETITE AND FRANKLINITE CRYSTALS FROM FRANKLIN FURNACE, NEW JERSEY

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MAGNETITE

Most people do not associate magnetite with Franklin Furnace. However in 1868, Dr. George H. Cook in his Geology of New Jersey mentioned two veins in this vicinity. The more continuous one was found in what was later designated as the Pochuck gneiss while the other occurred in the metamorphosed white Franklin limestone. More ore was produced from the gneiss but some was also obtained from the limestone. Both were mined by the Franklin Iron Company and the ore was smelted at the old Franklin charcoal furnace. The most important working in the gneiss was known as the Hill mine and was abandoned in February 1882. The one working in the crystalline limestone was called the Furnace or Pikes Peak Mine where work ceased in November 1881. In 1879 both properties together produced 14,000 tons of magnetite ore.

The writer while visiting Franklin in 1893 picked up a large magnetite crystal which by comparison with similar crystals in various collections seemed of such unusual size as to be worthy of record. The crystal under discussion was found on a dump from a trench excavation not very far from the New York, Susquehanna and Western Railroad tracks, southwest of the old furnace and near the first limestone quarry. This trench was in the limestone and was probably a continuation of the so-called Furnace vein. The magnetite crystal weighs 1205 grams and is about 9 by 9 by 10 centimeters, or about 3½ by 3½ by 4 inches. (Fig. 1). The crystal habit is rhombic dodecahedral with one face of the dodecahedron 7.5 centimeters between the two horizontal axes, and 5 centimeters high or 3 by 2 inches. The octahedral face above is from 2–2.5 centimeters or ¾–1 inch in length, and the dodecahedral faces are pronouncedly striated parallel to the intersecting edges with the octahedron. As the writer has previously indicated, he knows of no magnetite crystal any where which approaches this one in size.

Figure 1. Magnetite.

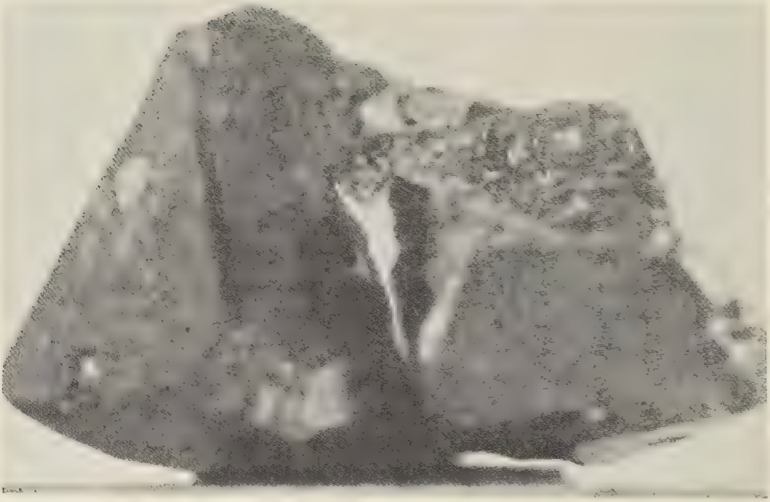

Figure 2. Franklinite.

FRANKLINITE

Large Franklinite crystals were not very unusual in the old days and in 1891, the writer found one rather imperfectly developed associated with calcite, zincite and tephroite. The specimen weighs 975 grams, and as usual the habit is octahedral with edges slightly truncated by the rhombic dodecahedron, the faces of which are about 10 centimeters or four inches long. The octahedron face is 8 centimeters or 3¼ inches between the dodecahedral faces.

A second specimen was found in 1893 and consisted of a group of two franklinite crystals which weighs 810 grams. (Fig. 2) The larger crystal is about 8 centimeters or 3¼ inches on the dodecahedral face while the octahedral face is between 5 and 6 centimeters or between 2 and 2½ inches long.

There is no doubt but that other franklinite crystals have been found as large as these but both specimens are, nevertheless, unusual in size.

THE USE OF THE OSCILLATION METHOD IN DETERMINING THE STRUCTURE OF ANALCITE

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INTRODUCTION

The optical anomalies of analcite, $NaAlSi_2O_6 \cdot H_2O$[1] have led mineralogists to suspect that analcite is not cubic but pseudo-cubic. X-ray investigations by the writer[2] have failed to furnish any clue as to its pseudo-structure, however. Analcite, therefore, may be regarded, for the present, as cubic holohedral. The forms (211) and (100) are well developed, as a rule, especially on crystals from the Cyclopean Islands which were used in this investigation. The oscillation spectrograms were made with the apparatus of Schiebold and Rinne.[3] For an understanding of the symbols and the terminology used in this paper it is essential that the reader refer to the paper "The oscillation method of X-ray analysis of crystals."[4] The references to it will be followed by "*Op. cit.*" in the text in order to avoid too many footnotes. The writer is greatly indebted to Prof. E. Schiebold and Prof. F. Rinne of the University of Leipzig, Germany, for the interest and help given to the author in this investigation.

The first step in the determination of a structure of a mineral is the measuring of the lengths of the edges of the unit cell and the finding of the fundamental Bravais lattice. Three of the fourteen Bravais lattices, the simple cube, the face-centered, and the body-centered cube, belong in the cubic system.

In the simple cube the three cube edges are the elementary primitive translations, that is the shortest vectors or *directed* distances from an atomic center to exactly identical atomic centers. The three elementary primitive translations in the face-centered cube are the three face-diagonal directions from one of the corner atoms. On them identical atomic centers are encountered at a distance of $\sqrt{2}/2 \cdot a_0$, a_0 being the length of the edge of the unit cube. The three elementary primitive translations in the body-centered cube are two edges a_0 and half the body diagonal which is $\sqrt{3}/2 \cdot a_0$ in length.[5]

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[1] Hintze, C., HANDBUCH DER MINERALOGIE, vol. 2, 1897, p. 1712. Doelter's HANDBUCH DER MINERALCHEMIE, vol. 2, 2. Hälfte, 1917, p. 350.

[2] Die Struktur des Analcims: I. Die Raumgruppe, *Zeit. f. Krist.*, in press.

[3] See Figs. 4a and 4b, Schiebold, E., Die Drehkristallmethode, *Fortschritte der Min., Krist. und Petrographie*, vol. XI, 1927, pp. 125–126.

[4] Gruner, John W.; *Am. Mineral.*, vol. 13, 1928, pp. 123–141.

It is obvious now that we can place a cubic crystal in its correct fundamental lattice, if we can measure the primitive translations in the directions of the cube edge [001], the cube face diagonal [110] and the body diagonal [111]. This can be done easily with the oscillation method. Three spectrograms of the crystal are necessary. Each one is a record of the crystal oscillated about one of the three directions given above.

Oscillation about the Edge of the Cube [001].

A good cube face of analcite is selected and mounted in the crystal holder (which may be similar to those on goniometers) in such a manner that the face is in a plane with the axis of oscillation and with the incident ray at the starting position. By "starting position" is meant the position of the crystal holder when the oscillating movement is reversed and the incident ray just parallels the crystal face. The face of the cube is turned in its plane till an edge [001] is parallel to the axis of oscillation. In order to get sharp-edged reflections on the photographic plate the Seemann wedge method is used. It consists in lowering a wedge of platinum or tungsten within 0.1 to 0.2 mm. of the crystal face in such a manner that the edge of the wedge lies exactly in the axis of oscillation.[6] This method insures a sharp edge on the side of the spot away from the axis of oscillation. The oscillation gear is set in motion after it is adjusted to turn 30° about the axis and then come back to the starting position. This motion is repeated at the rate of one oscillation in about 15 to 30 minutes. Monochromatic radiation from a molybdenum Coolidge tube was used for about two hours at 50 to 60 kilo volts and 5 to 6 milliamperes.

On the developed plate the middle of the sharp edge of each reflection is marked with India ink, by means of a dot and a number. The polar coordinates of each dot are recorded $\bar{\phi}$ in degrees and $\bar{r}$ in millimeters (*op. cit.* p. 127). The recording can be done best with a magnifying cyclometer. From the values $\bar{r}_{hkl}$ and

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[5] Bragg, W. H., and Bragg, W. L.; X-rays and Crystal Structure, *London* **1925**, p. 78.

Wyckoff, R. W. G., The Structure of Crystals, *New York*, **1924**, p. 56.

[6] Schiebold, E.; *op. cit.*, p. 140.

Wyckoff, R. W. G.; *op. cit.*, p. 166.

$\overline{\phi}_{hkl}$ of each spot the polar coordinates $R_0 \cdot \sin \alpha_{hkl}$ and $\rho_{p_{hkl}}$ of each point in the corresponding reciprocal lattice are calculated as follows.

Dividing $\bar{r}$ by r, the known distance from the axis of rotation to the photographic plate, the glancing angle α is obtained.

$$\frac{\bar{r}}{r} = \tan 2\alpha \qquad \text{Equation (3) } \textit{op. cit.}$$

With α and $\overline{\phi}$ the angle ρ_p is found.

$$\cos \rho_P = \cos \alpha \cdot \cos \overline{\phi} \qquad \text{Equation (7) } \textit{op. cit.}$$

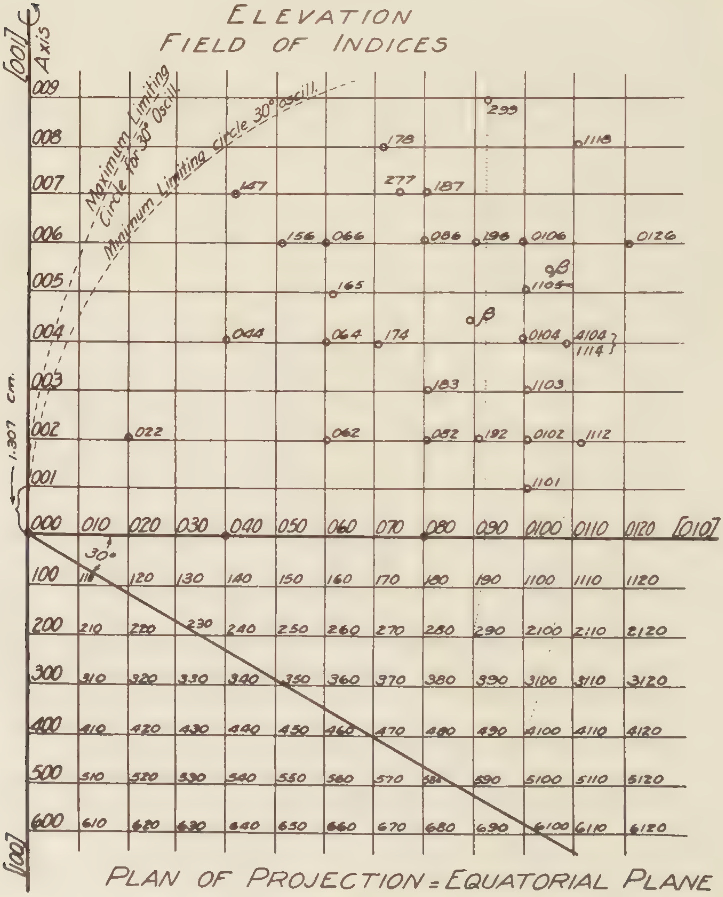

Figure 1.

$R_0 \cdot \sin \alpha$, the other coordinate is obtained by multiplying sin α by R_0, a constant. $R_0 = 500$ mm. The values for each sin α and ρ_p are given in the sixth and eighth columns of Table I. With these coordinates the points are plotted. The axis of rotation [001] is made the ordinate. The abscissa normal to the axis is the direction [010]. This is shown in the elevation of Fig. 1. Only the upper half of it is reproduced because the half on the photographic plate below [010] is symmetrical with respect to the upper one. (See for example Fig. 4). In Table I, however, all of the points of both halves are recorded. The plan below [010] in Fig. 1 is to be imagined as lying in the equatorial plane of the sphere of reflection at right angles to the axis of oscillation. The incident ray is parallel [100] at the starting position. Since an understanding of these directions is very important let a case in the orthorhombic system be considered, for illustration. Let the plane $a = (100)$ be taken. The directions [010] and [001] lie in it. These are the b and c axes, respectively. If we adjust the plane so that the direction [010] is parallel to the axis of oscillation and the plane is also parallel to the incident ray at the starting position, the direction [001] automatically has been made parallel to the incident ray at the starting position. The normal to the directions [001] and [010] obviously is the a axis or the direction [100]. In the reciprocal lattice the primitive translation a' (*op. cit.*, p. 129) is laid off in this direction [100] which is the abscissa in the projection. In other words that direction in the right-angled systems is the abscissa which is normal to the adjusted plane containing the axis of rotation and the incident ray at the starting position.

Returning to the case of analcite, the projection of the reciprocal lattice Fig. 1 reveals that the plotted points lie on parallel lines normal to the direction of the axis. They are the layer lines of I kind (*op. cit.*, p. 134) and equidistant from one another. This distance is $1/T_{001}$ (*op. cit.* Fig. 11), or we might say that it is the length h_{001} of the vector $\mathfrak{h}_{001}$ (the distance from 0 to point 001). But by equations (12) and (13) *op. cit.*

$$h_{001} = \frac{R_0 \lambda}{2 d_{001}} \tag{18}$$

Substituting for h_{001} the average measured distance 1.307 cm. between layer lines of I kind, for R_0 500 mm., for λ $0.70759 \cdot 10^{-8}$

cm. $= k\alpha$ radiation of the molybdenum target, and solving for d_{001} we get

$$d_{001} = \frac{50\text{cm} \cdot 0.70759 \cdot 10^{-8}\text{cm}}{2 \cdot 1.307\text{cm}} = 13.54\text{Å}$$

The length of the edge of the cube is 13.54 Å. This value is probably correct within 2 to 3 per cent.

The reflections in the projection are also arranged in lines parallel to the direction [001]. These are the layer lines of *II* kind. Since [001] and [010] are equivalent in the cubic system the distance 1.307 cm. is also laid off along [010] and lines parallel to the axis are drawn through these points. The resulting lattice of squares can be supplied with indices as shown. It will be noticed that many reflections lie at intersections. For these the indices may be read off directly by counting the lines in the directions [010] and [001]. The indices must satisfy the equation:

$$s = hu + kv + lw = 0,\ \pm 1,\ \pm 2,\ \pm\text{integer}\ (\textit{op. cit.}, \text{p. } 138) \qquad (19)$$

in which s is the index of summation, that is the number of the layer lines of *I* kind and $[uvw]$ the axis of oscillation, in our case [001]. Therefore the equation is simplified to:

$$s = l = 0,\ \pm 1,\ \pm 2,\ \pm\text{integer}$$

The two equations for the layer lines of *II* kind are: (*op. cit.*, p. 140)

$$h' = hu_1 + kv_1 + lw_1 = \text{constant} \qquad (20)$$

$$k' = hu_2 + kv_2 + lw_2 = \text{constant} \qquad (21)$$

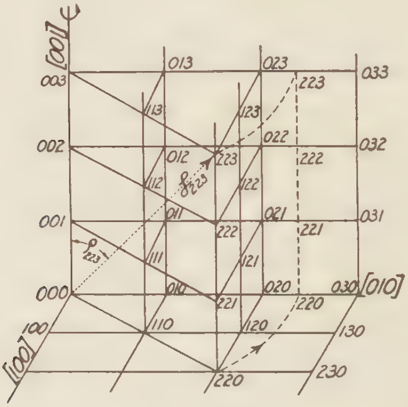

Figure 2.

Since $[u_1v_1w_1]$ and $[u_2v_2w_2]$ coincide with the crystallographic axes $a=[100]$ and $b=[010]$, respectively, these equations become:

$h'=h=$ constant along each layer line,
$k'=k=$ constant along each layer line.

All three equations must be satisfied by all the indices. The points which in the projection (Fig. 1) lie between the intersections though along layer lines of *I* kind are caused by planes whose reciprocal lattice points do not lie in the plane ([001], [010]), as for example (223) in Fig. 2. It will be seen that the position and therefore the indices of such a point may be found by imagining the plane in which the axis [001] and point (223) lie turned about [001] until it coincides with the plane ([001], [010]), in Fig. 2. The plan in the equatorial plane (Fig. 1) is constructed for the purpose of finding the indices of such points. Perpendiculars are dropped from these points upon [010]. With the distance, from the foot of the line to the origin as radius, an arc is drawn through the plan about *O* as a center. The first two indices of the point in the elevation may be found where the arc meets a point in the plan. To be positive of this we must ascertain whether the point penetrates the sphere of reflection during oscillation. The sphere with the radius $R_0/2=250$ mm. is drawn on tracing cloth (Fig. 3). The circles representing the intersections of the layer lines of *I* kind with the sphere (*op. cit.*, Fig. 11) are also drawn in. Only eight are necessary because in Fig. 1 no point lies above layer line $s=8$. Their radii are found as indicated in Fig. 11, *op. cit.* The origin of Fig. 1 is pinned to a point on the periphery of the circle whose $R_0/2=250$ mm. Either drawing may be turned until [010] is tangent to the circle. This is the relation to each other at the starting position. The plan of Fig. 1, for a better understanding is shown in Fig. 3 where the full lines represent the starting position. Any point of the reciprocal lattice that is already inside the sphere in this position can not reflect. As the lattice is turned 30° about *O* some of its points penetrate the zero circle of the sphere. These points are able to reflect. Their projections will lie on the line [010] which contains the principal spectrum. All points in the plan of the drawing represent planes that have [001] as zone axis. The points of the reciprocal lattice above and below the equatorial plane also may penetrate the sphere and therefore may reflect. But it is obvious from Fig. 10, *op. cit.* that these points can not lie higher (or lower) than the equatorial plane than $R_0/2=250$

mm., the radius of the sphere of reflection. Therefore, a circle drawn on the elevation with radius = 250 mm. that passes through O and whose center lies on [010] contains all the points which can reflect. Another limitation for indices is imposed in the direction of the axis [001]. In Fig. 3 the position of the plan after turning through 30° is indicated by broken lines. It will be seen that no point that can reflect can have a larger angle Φ (*op. cit.*, Fig. 12) than 60°. This angle then determines the radius of the maximum limiting circle by the formula:

$$r_0 = \frac{R_0}{2} \cdot \sin \Phi \quad (\textit{op. cit.}, \text{p. } 141).$$

This radius can also be found graphically as is shown in Fig. 3, where the 60 degree line $OQ_{p\,maximum}$ is the diameter of the maximum limiting circle. It is obvious then that a maximum limiting circle of $r_0 = R_0/2 = 250$ mm. would require a rotation of 45°. The limiting circle for any point can be found graphically or by calculation provided the angle Φ is known. The circle marked "minimum limiting for 30° oscillation" includes all the possible points of the plane ([001], [010]) that can reflect. These points do not move beyond $\Phi = 30°$ at any time as shown in Fig. 3.

An example will illustrate the determination of the indices. The indices for the point between 099 and 0 10 9, Fig. 1, are desired. Since $s = l = 9$, its third index will be 9. The projection of point (290) in the plan upon [010] will meet the perpendicular from the point under consideration upon [010]. The indices are therefore 299. A check on the sphere of reflection shows that the point 299 passes through it during oscillation. Another example is point 4 10 4. Examination of Fig. 3 shows that theoretically it does not pass through the sphere during oscillation but it comes within a few degrees of it. Such points sometimes give reflections. There is a possibility that this point is not 4 10 4 but 1 11 4. It can not be 0 11 4 because the sum of the indices must be even in body centered cubes.[7]

In the principal spectrum along [010] there are two reflections (040) and (080). If their α angles are substituted in the Braggs' equation

$$n\lambda = 2d \cdot \sin \alpha \qquad (22)$$

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[7] See for example, Wyckoff, R. W. G.; *op. cit.*, pp. 215–16.

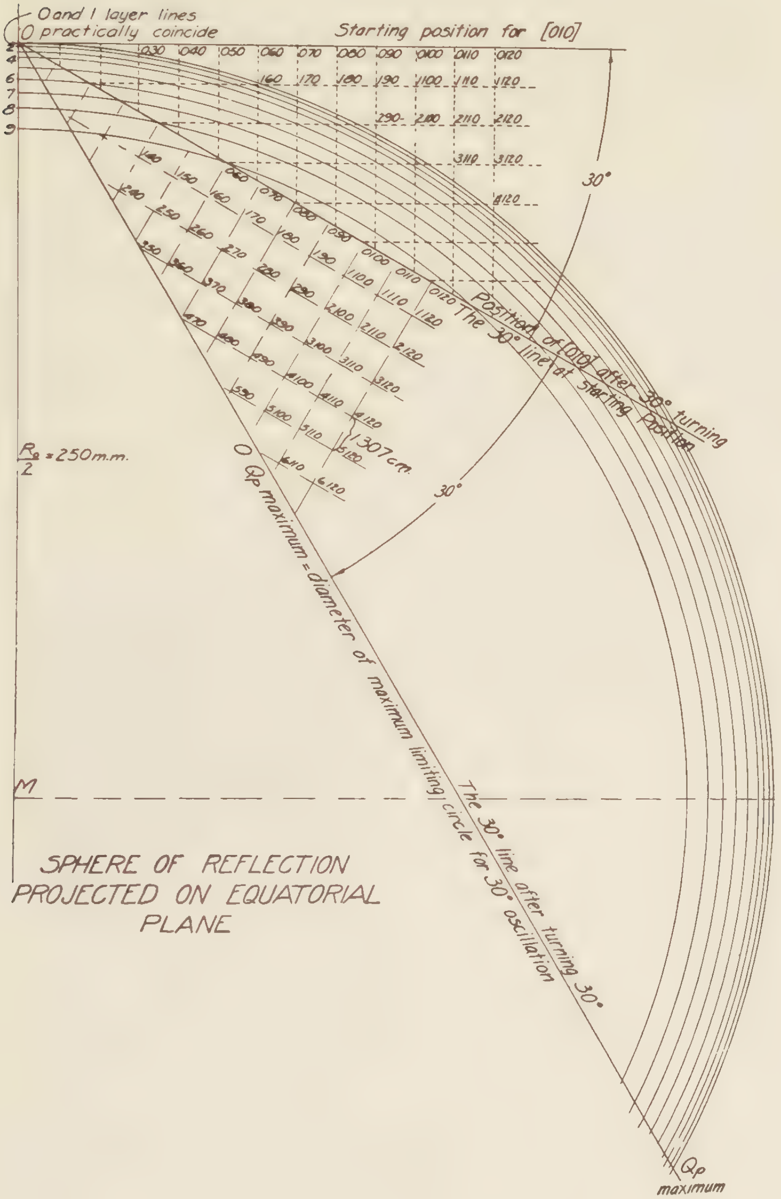
0 and 1 layer lines
0 practically coincide
Starting position for [010]
30°
1307 cm.
Position of [010] after 30° turning
The 30° line at starting Position
30°
$\frac{R_o}{2}$ = 250 m.m.
Qp maximum = diameter of maximum limiting circle for 30° oscillation
The 30° line after turning 30°
M
SPHERE OF REFLECTION PROJECTED ON EQUATORIAL PLANE
Qp maximum

Figure 3.

with their orders of reflection $n=4$ and 8, respectively, two values 13.539 Å and 13.595 Å for the length of the cube edge are obtained. Their average 13.567 Å is a more reliable value than that previously given. Still closer results can be obtained by precision measurements with calcite and analcite side by side on the crystal holder.[8]

All of the indices have been determined now with the exception of a few points which seem to lie on no layer lines at all. These points on examination will prove to be caused not by $k\alpha$ but by $k\beta$ ($\lambda=0.6311$ Å) radiation of molybdenum.[9] Since this radiation is much less intense, relatively strong $k\alpha$ reflections only will be accompanied by $k\beta$ reflections. This can be seen easily in the spectrograms Fig. 4 and 7. A $k\beta$ reflection always lies on a straight line connecting the corresponding $k\alpha$ reflection with the origin, and between these two points close to the $k\alpha$ reflection. It would be possible, of course, to use the $k\beta$ reflections for the construction of a reciprocal lattice if they were numerous enough by simply substituting the $k\beta$ wave length in the equations (18) and (22).

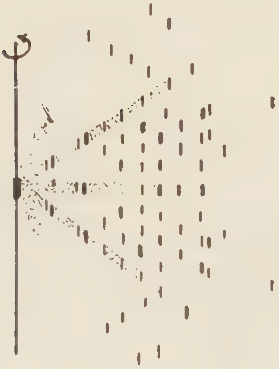

Figure 4.

Figure 7.

Figure 4. Spectrogram of analcite. Axis of oscillation parallel [$\bar{1}$01]. The direction [010] divides the spectrogram into two symmetrical parts.

Figure 7. Spectrogram of analcite. Axis of oscillation parallel to [111]. Since [111] is not normal to a plane of symmetry no symmetry as in Fig. 4 appears.

The first column of Table I contains all the indices for the spectrogram oscillated about [001]. The third column gives the approximate intensities, the fourth the spacing *d* of equivalent planes in the space lattice. Wherever two points are symmetrical with respect to the equatorial plane like (082) and (08$\bar{2}$) any blank spaces in the columns are to be filled in with the values just above them.

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[8] Wyckoff, R. S. G.; *op. cit.*, p. 174.

[9] Bragg, W. H. and W. L.; *op. cit.* p. 57.

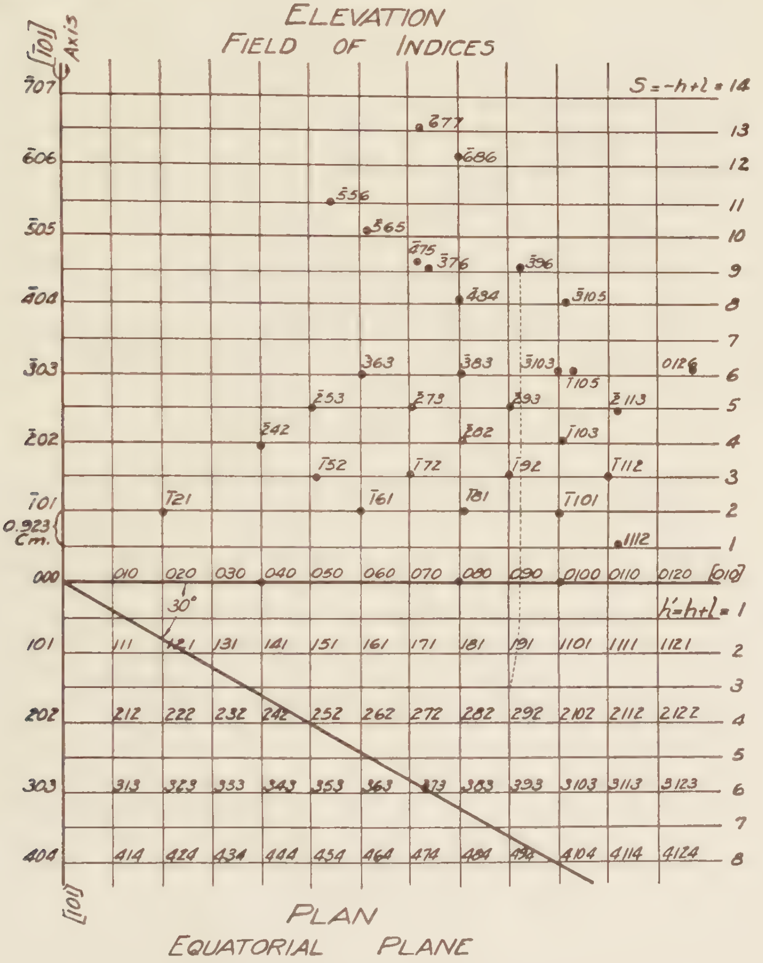

Figure 5.

OSCILLATION ABOUT THE FACE DIAGONAL [$\bar{1}$01]

The same face (010) as above is chosen. The directions [$\bar{1}$01] and [101] lie in it. The face is oriented as before but with the direction $[\bar{1}01]$ parallel to the axis of oscillation. $[101]$ is the direction of the incident beam therefore at the starting position. The direction $[010]$, is normal to these directions and therefore is the abscissa in the spectrogram Fig. 4 and in the reciprocal lattice, Fig. 5, as before. The angle of oscillation is 30°. The plotted projection of the reciprocal lattice (Fig. 5) shows the layer lines of I kind. They are separated by only $\sqrt{2}/2$ of the distance in the reciprocal lattice about $[001]$. Therefore the primitive translation $T_{\bar{1}01}$ in the space lattice is the reciprocal of $\sqrt{2}/2$ which is $\sqrt{2}\cdot a_0$. This makes it certain that the cube is *not* face-centered. Had it been face-centered the primitive translation $T_{\bar{1}01}$ would have been $\sqrt{2}/2\cdot a_0$, and only the even-numbered layer lines would have been occupied.

The spacing along $[010]$ in the reciprocal lattice remains the same as in Fig. 1. For the finding of the indices we use the equations (19) to (21). Since $[uvw]=[\bar{1}01]$ equation (19) becomes $s=h+l=0, \pm 1, \pm 2, \pm$integer, and (20) and (21) become:

$$h'=h+l=\text{constant}$$

$$k'=k=\text{constant}.$$

Some difficulty is encountered in finding indices for points on the odd-numbered layer lines. One would have been tempted to put the indices $[\bar{1}01]$ for example on the first layer line just above the origin 000, but equation (19) would not have been satisfied. Neither would the length $h_{\bar{1}01}$ of the vector $\mathfrak{h}_{\bar{1}01}$ in projection Fig. 5 have been the same as h_{011} in the projection Fig. 1 as it must be, if the equations (12) and (13) *op. cit.*, are correct. The fact that the lengths of vectors with the same indices are the same if the same scale has been used in the various projections constitutes an excellent check.

Let Fig. 6 represent a portion of the reciprocal lattice with indices at the corners of the cubes as shown. Let these points be projected on the plane containing the directions $[\bar{1}01]$ and $[010]$. It is seen that the points in the plane ($[101]$, $[010]$) are projected on the line $[010]$. Also those points lying on the normals to the plane ($[101]$, $[010]$) which have the intersections with this plane as origins (for example the normal 111, 012 with 111 as origin) are easily projected upon the even-numbered layer lines. This is done as illustrated in Fig. 2. But there are the points 001, 011, 021, $\bar{1}02$, and $\bar{1}12$. These are first projected upon the plane ($[101]$,

[010]) and from there upon the plane ([$\bar{1}$01], [010]) as illustrated by point 001 whose projection is P001. These projected points are always on odd numbered layer lines. Their indices must satisfy the equations (19) to (21) as those of the other points.

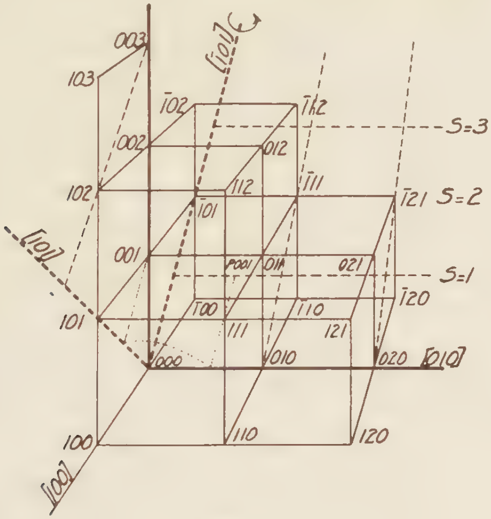

Figure 6.

Analytically the indices can be found easily. The modified equation (19) $-h+l=s$ is the equation of a plane parallel to the plane ([101], [010]). The modified equation (20) $h+l=h'$ represents a plane parallel to plane ([$\bar{1}$01], [010]). By solving these two simultaneously the equation of a straight line parallel to [010] is obtained which contains the point whose indices are wanted. This gives us the indices h and l. The point marked $\bar{3}96$ Fig. 5 is taken for illustration. Its indices are required. Projecting the point upon the equatorial plane it is found to lie on the line $h=3$. That gives us the two equations. Solving for l and h,

$$\begin{array}{r} -h+l=9 \\ \underline{h+l=3} \\ 2l=12 \end{array} \qquad (19)$$

$l=6$ and $h=-3$. The index for k is read off the plan. $\bar{3}96$ are the required indices. The limiting circles as well as the sphere of reflection are used as in the projections, Figs. 1 and 3. But the circles of the sphere have been drawn with radii which correspond to layer lines with a distance of $1/T_{\bar{1}01}$ apart.

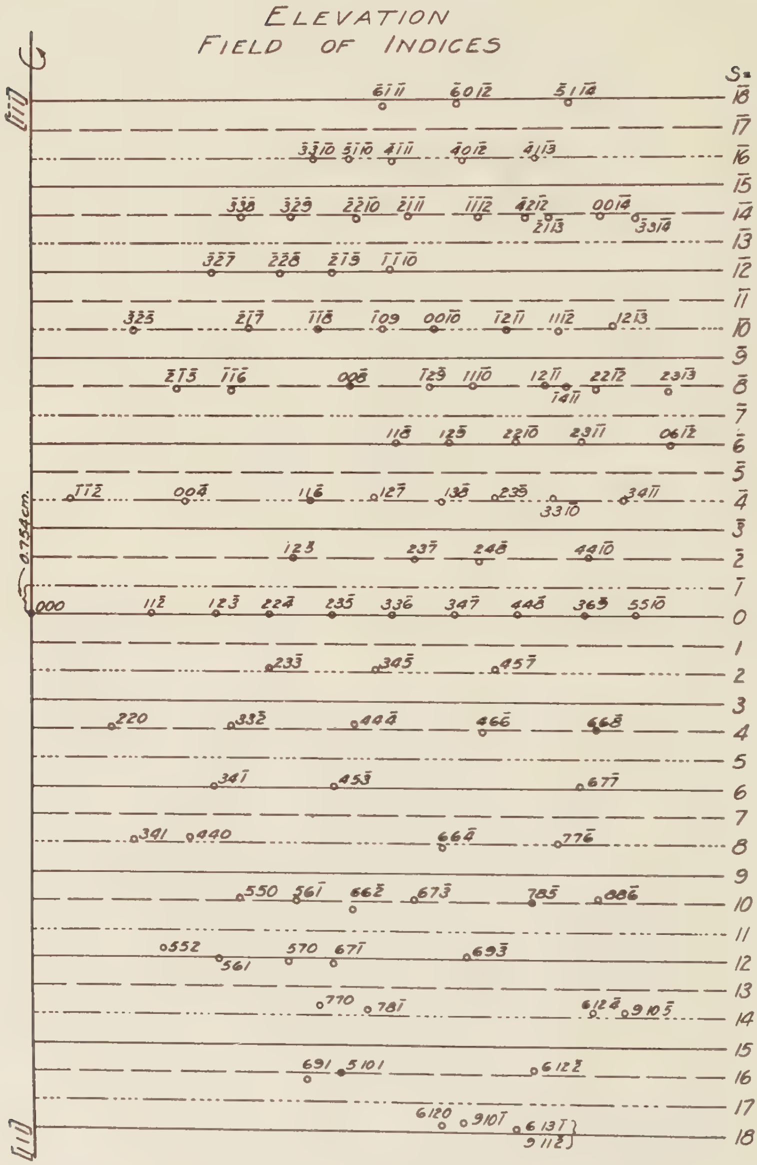
ELEVATION
FIELD OF INDICES
S=
[1̄1̄1̄]
[111]
0.754cm.
1̄8̄
1̄7̄
1̄6̄
1̄5̄
1̄4̄
1̄3̄
1̄2̄
1̄1̄
1̄0̄
9̄
8̄
7̄
6̄
5̄
4̄
3̄
2̄
1̄
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
6̄1̄1̄1̄
6̄01̄2̄
5̄11̄4̄
33̄1̄0̄
5̄1̄1̄0̄
4̄1̄1̄1̄
4̄01̄2̄
4̄11̄3̄
3̄3̄8̄
3̄2̄9̄
2̄2̄1̄0̄
2̄1̄1̄1̄
1̄1̄1̄2̄
4̄2̄1̄2̄
2̄1̄1̄3̄
001̄4̄
331̄4̄
3̄2̄7̄
2̄2̄8̄
2̄1̄9̄
1̄1̄1̄0̄
3̄2̄5̄
2̄1̄7̄
1̄1̄8̄
1̄09̄
001̄0̄
1̄21̄1̄
1̄11̄2̄
121̄3̄
2̄1̄5̄
1̄1̄6̄
008̄
1̄29̄
111̄0̄
121̄1̄
1̄41̄1̄
221̄2̄
231̄3̄
118̄
125̄
221̄0̄
231̄1̄
061̄2̄
1̄1̄2̄
004̄
116̄
127̄
138̄
239̄
331̄0̄
341̄1̄
123̄
237̄
248̄
441̄0̄
000
112̄
123̄
224̄
235̄
336̄
347̄
448̄
369̄
551̄0̄
233̄
345̄
457̄
220
332̄
444̄
466̄
668̄
341̄
453̄
677̄
341
440
664̄
776̄
550
561̄
662̄
673̄
785̄
886̄
552
561
570
671̄
693̄
770
781̄
6124̄
9105̄
691
5101
6122̄
6120
9101̄
6131̄
9112̄

Figure 8.

OSCILLATION ABOUT THE BODY DIAGONAL [111].

The direction [111] lies in the face $11\bar{2}$ (Tetragonal trisoctahedron), which is well developed on analcite. $[\bar{1}10]$ is normal to [111] in this face. Let the face $11\bar{2}$ be oriented on the crystal holder in such a way that [111] is parallel to the axis of rotation and $[\bar{1}10]$ is parallel to the incident ray at the starting position. The angle of oscillation is 30°. A very large number of reflections are recorded on the photographic plate, Fig. 7. The lower half is not symmetrical with respect to the upper half since the axis [111] is not normal to a plane of symmetry. The plotting of the indices in the projection of the reciprocal lattice (Fig. 8) shows that only even-numbered layer lines of *I* kind are occupied. The distance between layer lines is $1/T_{111}$. But $T_{111}=a_0\sqrt{3}$. Therefore, $1/T_{111}=1/a_0\sqrt{3}=0.7545$ cm. by equation (18). Since only even-numbered lines are occupied, the primitive translation T_{111} which is the reciprocal of the distance between occupied layer lines is $a_0\sqrt{3}/2$. This shows at once that analcite is body-centered. The plan of the projection is constructed with $[11\bar{2}]$ as the abscissa and $[\bar{1}10]$ as the ordinate. This relationship is seen best in the stereographic projection Fig. 10 in which 111 is taken as the center. It will be noticed that [011], which is equivalent to $[\bar{1}10]$, lies in the plan (Fig. 11) at 60° from $[\bar{1}10]$. Since we know the distance $h_{\bar{1}10}=(h_{0\bar{1}1})$ from the other projections it may be laid off along $[\bar{1}10]$ and $[01\bar{1}]$. A rhombic lattice is obtained in this way as shown by the full lines in Fig. 11 which is the plan of the elevation of Fig. 8. Its indices are found most easily by the equations (19), (20) and (21). They reduce to:

$s=l'=h+k+l=0$ (because the points lie in the plane.)
$h'=-h+k=0,\ \pm,\ 1\pm,\ 2\pm$integer.
$k'=h+k-2l=0,\ \pm 1,\ \pm 2,\ \pm$integer.

These equations represent planes normal to the directions [111], $[\bar{1}10]$ and $[11\bar{2}]$ respectively. l', h', k' are integers including zero which give the number of planes from the origin to the point whose indices are required. Let the point 134 in the plan be taken as illustration. The equations are:

$$h+k+l=0$$
$$-h+k=2$$
$$h+k-2l=12^{10}$$

---

[10] In counting the planes the full as well as the broken lines are counted.

Solving for *h, k* and *l*, the indices are $13\bar{4}$.

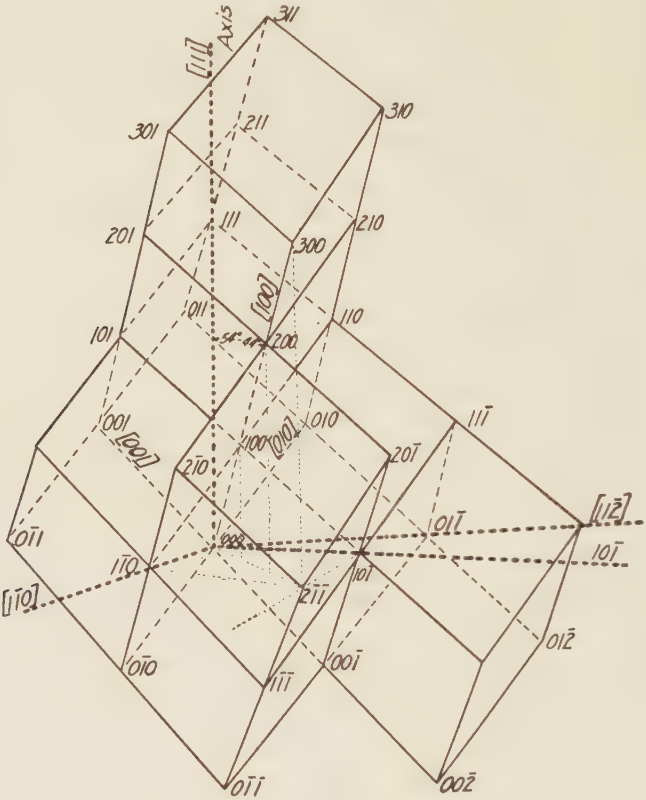

Figure 9.

With only the O plan in full lines it is not possible to find the indices of all the reflections. The portion of the reciprocal lattice reproduced in Fig. 9 shows the plane in which $[1\bar{1}0]$ $[10\bar{1}]$ and $[11\bar{2}]$ lie. By a slight oversight Fig. 9 was made the mirror image of Fig. 11 with respect to the plane ($[111]$, $[11\bar{2}]$) which is a plane of symmetry. This interchange may be seen at a glance in the stereographic projection of Fig. 10. The indices of one side can be converted into those of the other side by exchanging the first and second indices. A study of Fig. 9 shows that the points of the next plane above the ground plan do not coincide with those in the ground plan when projected perpendicularly. Neither does the second one. The third one, however, which contains the points 111 and 300 coincides exactly. 300, for example, lies perpendicularly above $2\bar{1}\bar{1}$ of the ground plan. The points of the first plane, on the other hand, are displaced one third and those of the second plane two thirds and along the line (000, $2\bar{1}\bar{1}$) as illustrated by the projection of the points 100 and 200. This displacement really makes three plans necessary as shown in Fig. 11 by three sets of lines of different patterns. These plans may be called the *O*, the *I* and *II* plans. The *O* plan is used for the projection of indices upon every third layer line in the [111] as well as in the [$\bar{1}1\bar{1}$] direction of Fig. 8, in other words upon the 0, ±3, ±6, etc., lines. The *I* plan is used also for every third line as counted from the layer line $s=1$. The 1, 4, 7, etc., and the $\bar{2}$, $\bar{5}$, $\bar{8}$, etc., layer lines receive their indices from it. The *II* plan is used for the remaining lines 2, 5, 8, etc., and $\bar{1}$, $\bar{4}$, $\bar{7}$, etc. The indices must satisfy the equation (19) which reduces to:

$$h+k+l=s$$

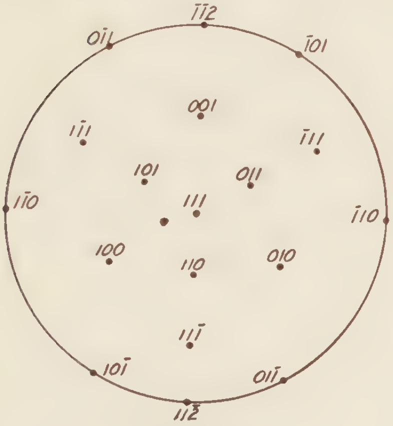

Figure 10.

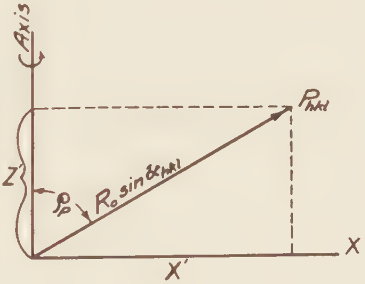

Figure 12.

The equation for layer lines of *II* kind are unreliable here because there are no marked lines in Figs. 7 and 8 parallel to the axis [111]. Inspection of Fig. 9 shows that the nearest point lying perpendicularly above another has each index increased by 1 algebraically. This is obvious because s(=number of layer lines) increases by 3 for each set of 3 layer lines. For example: A point in layer line 8 (the positive direction of 111 happens to be downward in Fig. 8) is found by projection to be above $34\bar{5}$ in the *II* plan. Since layer line 8 is 6 lines above line 2, which corresponds to the *II* plan, two is added to each index. The indices for the point are $56\bar{3}$. A reliable check for these indices is given below.

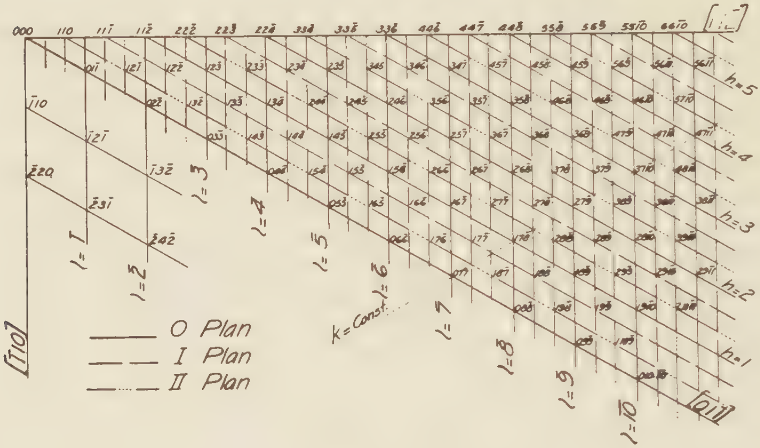

Figure 11.

Recalculation of the Angles $\bar{\phi}$ and α.

The best check on the correctness of the assigned indices is the recalculation of sin α_{hkl} and cos $\rho_{p_{hkl}}$ and $\bar{\phi}_{hkl}$, respectively, by means of these indices. By equation (22)

$$\sin \alpha_{hkl} = \frac{\lambda}{2d_{hkl}} = \frac{0.3538 \cdot 10^{-8}\text{cm}}{d_hk_l}\cdot$$

$$d_{hkl} = \frac{a_0}{\sqrt{h^2+k^2+l^2}}$$

in the cubic system.[11]

Substituting the assigned indices in these equations (without making the indices prime) the calculated values of sin α given in the fifth column of Table I are obtained. They agree closely with the measured values.[12] ρ_p is evaluated as follows. P_{hkl} is the point of the reciprocal lattice with the polar coordinates ρ_p and $R_0 \cdot$ sin α_{hkl} in Fig. 12. z' is the distance between layer lines taken s times. Therefore $z'=s\cdot 1/T_{u_3v_3w_3}$. The right side of the equation must be multiplied by the constant of the drawing $R_0\lambda/2$, *op. cit.* (13). Then

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[11] Wyckoff, R. W. G.; *op. cit.*, p. 96.

[12] Schiebold, E.; *op. cit.*, p. 251.

$$z'=\frac{R_0\cdot\lambda\cdot s}{2T_{u_3v_3w_3}} \tag{23}$$

but $$\frac{z'}{R_0\sin\alpha_{hkl}}=\cos\rho_P$$ see Fig. 12).

Substituting (23) for z'

$$\cos\rho_P=\frac{s\cdot\lambda}{2T_{u_3v_3w_3}\cdot\sin\alpha_{hkl}} \tag{24}$$

But by (22) $$\frac{\lambda}{2\sin\alpha_{hkl}}=d_{hkl}$$

Substituting in (24)

$$\cos\rho_P=\frac{s\cdot d_{hkl}}{T_{u_3v_3w_3}} \tag{25}$$

It would be sufficient to compare the value of ρ_p of (25) with the ρ_p calculated from the measured $\bar{\phi}$ and $\bar{r}$ on the photographic plate. By equation (7) *op. cit.* $\bar{\phi}$ was calculated.

$$\cos\bar{\phi}=\frac{\cos\rho_P}{\cos\alpha}$$

The calculated $\bar{\phi}$ values are given in the *7th* column of Table I. They should agree to within one degree with the measured values though for points far from the origin the difference may be slightly larger.

DETERMINATION OF THE NUMBER OF MOLECULES IN UNIT CELL.

The molecular weight M of $NaAlSi_2O_6\cdot H_2O$ is 219.70. The density S as determined by various investigators[13] is 2.26. The volume V of the unit cell is $(13.64\cdot 10^{-8}\text{ cm.})^3$. The value 13.64 Å was determined by averaging the results of three powder diagrams.[14] It was taken in preference to 13.567 Å because it was an average of a great number of lines. Substituting these values in the well known formula

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[13] Doelter's HANDBUCH, *op. cit.*

$$Z=\frac{V\cdot S}{M\cdot 164\cdot 10^{-24}}=\frac{(13.64)^3\cdot 2.26}{219.70\cdot 1.64}=15.92+$$

$Z=15.92+$ is the number of molecules in the unit cell. Since the number must be an integer 16 molecules is taken as the number in the cell.

THE SPACE GROUP OF ANALCITE.

Since analcite is cubic holohedral and body-centered, only the two space groups[15] $O_h{}^9$ and $O_h{}^{10}$ need to be considered. The choice between these two space groups depends upon the presence or or absence respectively of certain reflections.[16] It appears that the group $O_h{}^9$ is the correct one since a number of reflections with the indices $(0kl)$, where k and l are odd, appear in the I order. Also first order reflections of (hll), where $\frac{1}{2}h$ is even and l odd, seem to be present. Unfortunately in these cases possible reflections of faces which do not violate the requirements of space group $O_h{}^{10}$ can be found which give us practically as good values for the sin α and the angle $\bar{\phi}$ as those measured in the oscillation spectrograms.

SUMMARY.

The oscillation method is used in the determination of the space group of analcite. It is shown how an oscillation diagram about a prominent crystallographic direction as an axis furnishes the primitive translation in this direction; i.e., the distance between identical atoms. For a cubic crystal three oscillation spectrograms are necessary, one with the axis parallel to the edge of the cube [001], the second parallel to the face diagonal [110], and the third parallel to the body diagonal [111]. Each spectrogram is evaluated and plotted on the reciprocal lattice. The indices for each point are found graphically. These indices are used in the recalculations of the positions of the reflections in the spectrograms. If the agreement is close the indices are correct.

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[14] Gruner, J. W.; *Zeitschr. f. Krist., op. cit.*

[15] Wyckoff, R. W. G.; The analytical expression of the results of the theory of space groups: Carnegie Institution, *Washington*, **1922.**

[16] Wyckoff, R. W. G.; The Determination of the Space Group of a Cubic Crystal. *Am. Jour. Sci.*, vol. **4**, pp. 175–187, 1922.

Analcite has the cubic holohedral lattice and seems to belong to the space group O_h^9. However, the reflections agree practically as well with the requirements of space group O_h^{10}. The correct choice between these two groups will have to be based on other considerations which can not be discussed at this time. The unit cube contains 16 molecules of $NaAlSi_2O_6H_2O$. Its edge is 13.64 ± 0.05 Å long.

TABLE I

OSCILLATION SPECTROGRAM ABOUT [001]. STARTING POSITION (010).

Indices	*Layer line = s*	*Indensity*	*d*	sin α		$\bar{\phi}$	
				calculated	*measured*	*calculated*	*measured*
0 4 0	0	1	3.410	.1037	.1045	90°00	90°00
0 8 0	0	1–2	1.076	.2072	.2082	90°00	90°00
1 10 1	1	2	1.351	.2619	.2627	84°06	84°24
1 10 $\bar{1}$	$\bar{1}$	2			.2620		83°30
0 2 2	2	3	4.823	.0733	.0735	44°51	44°54
0 6 2	2	5	2.157	.1640	.1636	71°45	71°42
0 6 $\bar{2}$	$\bar{2}$	5			.1639		71°42
0 8 2	2	3	1.658	.2134	.2139	75°36	76°36
0 8 $\bar{2}$	$\bar{2}$	3			.2150		74°48
1 9 2	2	3	1.475	.2398	.2416	77°08	77°30
1 9 $\bar{2}$	$\bar{2}$	3			.2410		76°30
0 10 2	2	5	1.351	.2646	.2654	78°09	78°36
0 10 $\bar{2}$	$\bar{2}$	5			.2658		77°36
1 11 2	2	5	1.215	.2911	.2910	79°16	79°42
1 8 3	3	3	1.586	.2230	.2232	69°02	69°36
1 8 $\bar{3}$	$\bar{3}$	3			.2238		67°48
1 10 3	3	4	1.300	.2722	.2726	72°43	73°12
1 10 $\bar{3}$	$\bar{3}$	4			.2719		71°42
0 4 4	4	2–3	2.412	.1467	.1460	44°21	44°54
0 6 4	4	2	1.889	.1873	.1868	55°41	56°18
0 6 $\bar{4}$	$\bar{4}$	2			.1874		55°00
1 7 4	4	4	1.678	.2108	.2090	59°46	61°18
1 7 $\bar{4}$	$\bar{4}$	4			.2113		58°30
0 10 4	4	4	1.266	.2794	.2801	67°15	67°18
0 10 $\bar{4}$	$\bar{4}$	4			.2810		66°24
4 10 4	4	5	1.187	.2981	.3004	68°39	69°48
1 6 5	5	4	1.732	.2043	.2048	47°47	50°48
1 6 $\bar{5}$	$\bar{5}$	3			.2048		48°18
1 10 5	5	4	1.215	.2911	.2910	61°10	63°00
1 10 $\bar{5}$	$\bar{5}$	4			.2910		61°42
1 5 6	6	4	1.732	.2043	.2051	38°53	39°54
0 6 6	6	3	1.607	.2201	.2193	43°33	43°06
0 8 6	6	2–3	1.364	.2594	.2606	51°36	52°00
0 8 $\bar{6}$	$\bar{6}$	3			.2599		51°06
1 9 6	6	4	1.255	.2818	.2810	54°51	55°48
1 9 $\bar{6}$	$\bar{6}$	4			.2810		54°54
0 10 6	6	5	1.166	.3033	.3021	57°25	57°36
1 12 6	6	5	1.016	.3480	.3461	61°30	62°18
1 4 7	7	3	1.678	.2108	.2119	28°10	29°24
1 8 7	7	3	1.277	.2769	.2773	46°48	47°42
1 8 $\bar{7}$	$\bar{7}$	3			.2773		46°12
1 7 8	8	3	1.277	.2769	.2773	38°45	39°30
1 7 $\bar{8}$	$\bar{8}$	4			.2773		38°00
1 11 8	8	4	1.016	.3480	.3537	51°04	51°48
2 9 9	9	4	1.058	.3342	.3346	42°13	43°12
2 9 $\bar{9}$	$\bar{9}$	4			.3341		41°18
2 7 7	7	3	1.351	.2619	.2642	45°12	45°12
2 7 $\bar{7}$	$\bar{7}$	2			.2647		43°30

SEDIMENTARY ANALCITE[1]

CLARENCE S. ROSS, *U. S. Geological Survey.*

In October, 1925, Mr. H. L. McCarn, a mining engineer of Chloride, Arizona, submitted a group of specimens to the United States Geological Survey for identification, and an examination indicated that part of the material was so unusual that a detailed study and report seemed to be justified.

The material resembles a fine grained, friable green sandstone It was used as a building stone in some outbuildings at the Neal ranch across Sandy Creek from Wikieup post office, and came from a small gulch only a short distance from the banks of the Big Sandy on the Burro Creek road which crosses the Aquarius Cliffs in western Yavapai County, Arizona. Mr. McCarn states that these are sedimentary beds and were evidently Quaternary lake beds or playa deposits. The underlying material was a very fine grained, highly indurated greenish shale.

Microscopic examinations showed that the sandstone-like specimen is made up almost exclusively of small crystal grains. These range from 0.04 to 0.10 and average 0.06 of a millimeter in diameter, and a large proportion are perfect trapezohedrons; many are free individual crystals but others appear to be fused together into groups and irregular chains. Each grain is surrounded by a thin film of glauconitic material which gives it a greenish color. A slight banding effect is produced in the sandstone-like bed by differences in the proportion of the green film around the original grains and in the depth of the green color so produced. A fraction of 1 per cent of quartz, plagioclase and augite are the only other minerals present.

The optical properties are as follows: Isotropic; index of refraction 1.483; crystal form trapezohedron; specific gravity 2.26. The crystals contain cloudy inclusions that have a nearly concentric arrangement and probably represent opaline silica since the material is isotropic and the index of refraction is low. Crystals that have been approximately freed from the glauconitic coatings are a light gray green.

The following chemical analyses have been made of material that had been almost completely freed from the enclosing films of glauconite.

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[1] Published by permission of the Director of the U. S. Geological Survey.

Analyses: Analcite from Yavapai Co., Arizona

I

	Per cent.		Ratios	
SiO_2	60.61	1.005	253	253 excess SiO_2
			752	400
Al_2O_3	18.03	0.176	176	94
Fe_2O_3	1.01	0.006	6	
FeO	Undet.			
MgO	0.05	0.001	1	
CaO	0.04	0.001	1	
Na_2O	10.98	0.177	188	100
K_2O	1.02	0.011		
H_2O-	0.34		88	88 excess H_2O
H_2O+	8.36	0.464	376	206
	100.44			

II

	Per cent.		Ratios	
SiO_2	58.8	.975	275	275 excess SiO_2
			700	400
Al_2O_3	17.9	.175	175	100
Fe_2O_3	2.2	.014	14	
FeO	0.1	.001	1	
MgO	0.8	.020	20	
CaO	0.5	.009	9	
Na_2O	9.8	.158	174	100
K_2O	1.5	.016		
H_2O-			127	127 excess H_2O
H_2O+	8.6	.477	350	200
	100.2			

In these analyses the ratio of Al_2O_3 to Na_2O+K_2O is approximately 1 to 1 as it should be for analcite. In analysis I there is an excess of 15.25 per cent. of SiO_2 and 1.59 of H_2O. In analysis II there is 19.6 per cent. excess of SiO_2 and 2.3 of H_2O. Fe_2O_3, FeO, MgO and CaO total about 1.0 per cent. of analysis I and 3.6 per cent. of analysis II and are probably derived largely from glauconite that was not entirely removed before analysis. The excess silica and part of the water are probably present as opal inclusions in the analcite.

Thus the crystal form, the optical properties and the chemical composition indicate that the crystals are analcite.

It is remarkable to find a rock in a sedimentary series that is composed almost exclusively of analcite. Mr. McCarn is undoubtedly correct in believing that it is part of a lake bottom or playa deposit. The method by which sedimentary analcite is formed presents an interesting problem. It seems evident that sodium salts which were concentrated in a playa lake were the initial cause of this formation of analcite. The reaction between sodium salts and feldspar has been suggested as the mode of formation, but a small amount of perfectly fresh plagioclase is associated with the analcite grains and so it is evident that feldspar was stable under the conditions that prevailed during the formation of analcite. Playa deposits often contain beds of exceedingly fine grained or colloidal clay and it is possible that reactions between colloidal, hydrous aluminum silicates and sodium salts may have produced analcite. On the other hand volcanic ash showers frequently deposited beds of glassy ash in these playa lakes. Material of this kind commonly alters to bentonite but in the presence of concentrated sodium salts it might form analcite. A small proportion of minerals similar to those found in volcanic ash are associated with analcite but these are smaller in amount than in most ash deposits. With the information at hand it is impossible to decide between these two possible modes of origin for this analcite, but the sedimentary character can not be doubted. It is formed in part from detrital sediments and in part from chemical elements that were held in solution. Its origin therefore is a combination of mechanical deposition and chemical precipitation.

Mr. W. H. Bradley,[2] of the United States Geological Survey, has just described a similar occurrence of analcite. In the summer of 1925 sandstone-like beds of euhedral analcite that reach a maximum diameter of two millimeters were found in the Green River formation of Utah, Colorado and Wyoming. Bradley says "Field and microscopic study of these two types of zeolite-bearing rocks indicate that both minerals (analcite and apophyllite) formed in place on the lake bottom (or when only shallowly buried in ooze) as a result of interactions between various salts dissolved in the lake water and the dissolution products of volcanic ash that fell into the ancient Green River lakes."

[2] Bradley, W. H.; Zeolite beds in the Green River formation: *Science*, vol. **67**, pp. 73, 74, 1928.

NOTES AND NEWS

ARRANGEMENT OF THE SYMMETRY-CLASSES

Edgar T. Wherry, *Washington, D. C.*

A year ago I published in this Journal[1] a set of relatively simple names for the symmetry-classes, arranging these classes in a table which brought out to some extent analogies between the several crystal systems. At the time Professor Austin F. Rogers kindly called my attention to the fact that I was listing as trigonal certain classes which were considered by space-group theorists as hexagonal, but as this had no bearing on the working out of the new names which was the primary object of that paper, no attempt was made to introduce the corresponding changes in the tabular arrangement. The subject having recently been brought to attention again by the appearance of two German articles,[2] I now wish to place on record an improved and mathematically more acceptable tabulation of the crystal classes, which brings out to the maximum extent the relations between the classes in the several systems.

In order that the question as to the preferable names to be applied shall not enter and distract attention from the main purpose, the classes are referred to merely by minerals or inorganic compounds currently believed to typify them. As before, it must be clearly understood that the symmetry-classes in question may be in many cases merely representative of the habit or superficial symmetry of the substance, and not of the internal structure; but at any rate when the classes of wulfenite, nephelite, cuprite, etc., are enumerated, reference to any recent book on crystallography will furnish data as to exactly what symmetry is possessed by those classes. This time the table starts with minimum symmetry and proceeds to maximum, although it can be inverted if anyone desires to go the other way.

Trimetric Division

Triclinic	Ca-thiosulf.	....	....	....	....	chalcanthite
Monoclinic	....	....	Li-sulfate	clinohedrite	....	gypsum
Rhombic	....	....	epsomite	hemimorphite	....	barite

Dimetric Division

Tetra-	2f.	....	meliphanite	....	....	chalcopyrite	....
gonal	4f.	wulfenite	scheelite	Ni-sulfate	Ag-fluoride	....	octahedrite
Hex-	3f.	Na-period.	....	quartz	tourmaline	....	....
ag-	3′f.	....	(unknown)	....	....	benitoite	....
on-	3″f.	....	dolomite	....	....	calcite	....
al	6f.	nephelite	apatite	high-quartz	iodyrite	....	beryl

Monometric Division

Cubic	ullmannite	pyrite	cuprite	sphalerite	....	fluorite

Novel features in this tabulation are: Grouping of the crystal systems into three *divisions*. Many students seem able to appreciate the axial features of curved surface solids better than polyhedrons, at the start, and it is easy to take up, then, an ellipsoid, cylinder and sphere respectively, and show how the respective systems can be derived by symmetrical flattening of these solids. The optical features of biaxiality, uniaxiality and isotropism also successively characterize these divisions.

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[1] *Amer. Mineral.*, 12 (5), 218, 1927.

[2] F. Becke, *Fortschr. Min. Krist. Petr.*, 12, 97, 1927; F. Rinne, *idem*, p. 107.

The Tetragonal system is divided into two sub-systems, the Hexagonal into *four*, distinguished by the rotation symmetry of their singular directions or axes. Anyone who prefers to set up a Trigonal system as distinct from the Hexagonal can combine these sub-systems as desired. If they are to be consistent, however, they should then recognize also a Digonal system made up of the classes of the Tetragonal with 2 fold symmetry of the singular axis.

The classes of minimum symmetry within each system or sub-system appear in an early class-column, those of maximum symmetry (holosymmetry) in a late one. The second class-column contains those classes characterized by third-order forms in each of the dimetric subsystems; the third, those classes similarly characterized by trapezohedrons; and the fourth, those characterized by hemimorphism with otherwise complete symmetry. In general, it is believed that this arrangement has advantages over previous ones in bringing out similarities between analogous classes in different systems which may be of pedagogical value; and it is hoped that it is correct from the mathematical standpoint. Suggestions for its improvement will, however, be welcome.

THE PRONUNCIATION OF PYROXENE.

Frederick A. Burt, *Agricultural and Mechanical College of Texas.*

During several years of teaching experience the writer has been located in a portion of Texas where he comes in contact with many oil geologists whose combined geologic training represents most of our universities and colleges which have well-established departments of the geologic sciences. Among these men *pyroxene* seems to be the most variously pronounced word in their scientific vocabularies, and this fact must reflect upon the pronunciation used by our corps of mineralogy, petrology, and geology instructors.

Five ways of pronouncing the word seem common: (1) pī′-rŏk-sēn, (2) pī′-rŏks-ēn, (3) pĭr′-ŏk-sēn, (4) pī-rŏks′-ēn, and (5) pĭr-ŏks′-ēn. A note on the origin and pronunciation of this word, therefore, seems in order.

The term *pyroxene* was established by Haüy (in 1796), being coined by him from two Greek words: pyr (fire), and xenos (a stranger), since he erroneously thought the mineral alien to igneous rocks.

The new Webster Unabridged Dictionary[1] gives "(1)" above preference and "(3)" as an alternative pronunciation. Funk and Wagnalls New Standard gives "(2)" as preference and "(3)" as an alternative. Here is practical agreement between the two works with the preference on a long *i*-sound in the first syllable, and an alternative of the short *i*-sound. The question of whether the *s*-sound should terminate the second or originate the third syllable seems of slight importance. No authority can be found for placing the accent on the second syllable.

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[1] The mineralogical terms in Webster were edited by E. S. Dana, in the new Standard by Frank W. Clarke.

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Regular Monthly Meeting of January 18, 1928.

A regular monthly meeting of the New York Mineralogical Club was held in the Academy Room of the American Museum of Natural History, on the evening of January 18 at 8:15 P.M. The President introduced the speaker of the evening, Dr. Alfred C. Hawkins of Rutgers College, who spoke on "*Blowpipe Analysis.*" Dr. Hawkins outlined the methods of dry chemistry which constitute the essentials of analysis with the blowpipe, and mentioned briefly some of the standard text books on the subject. Entering into a more detailed description of apparatus and methods, he touched upon the various sets employed, from the elaborate one used at Princeton to a miner's field kit. He demonstrated the oxidizing and reducing flames by means of a Bunsen burner converted into a blowpipe lamp by the insertion of a tube flattened at the end. He showed some of the results of tests for volatile metals by sublimates on plaster and charcoal supports, and the use of open and closed tubes in testing for arsenic, antimony and mercury. The speaker then outlined a method of procedure to be followed in blowpipe determinations.

In the discussion Dr. Allen spoke of Prof. S. L. Penfield of Yale, as having been especially expert in this method of analysis and showed a cobalt nitrate solution bulb of the Penfield pattern which had been blown by Prof. Penfield and sealed by Dr. Allen, so that the original cobalt nitrate solution was still in the bulb after the lapse of many years.

Mr. Whitlock described some of the apparatus in use in the Blowpipe Laboratory of Columbia in the '80's, especially the old Plattner oil burning lamp, and described an original scheme of magnetic separation by means of a thin paper "guard" held against the magnet.

A vote of thanks was tendered to Dr. Hawkins for his very able and interesting talk.

HERBERT P. WHITLOCK, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, March 1, 1928.

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with an attendance of twenty-nine members and eleven visitors. The president, Mr. Clay, presided. Mr. L. W. Strock was elected to membership and Mr. Arthur Criley to junior membership.

Mr. B. B. Weatherby of the University of Pennsylvania addressed the society on "*The use of geophysical instruments in discovering mineral and oil deposits.*" The speaker described the new instruments that have found application in the Gulf States for locating salt domes, anticlines and faults. The use of the torsion balance, the seismograph and the magnetometer were described in detail and the results obtained with each and their comparative merits were spoken of.

A trip to French Creek, with finds of pyrite showing pyritohedrons, was reported by Mr. Oldach. Other trips were reported by Messrs. Warford, Hoadley, Cienkowski and Wolf.

F. A. CAJORI, *Secretary.*

NEW MINERAL NAMES

"Mellahite"

ENRICO NICCOLI: *Giorm. Chim. und Applicata*, **8**, 309–313, (1926).

A name applied to the mixed salts obtained from the Mellaha salines by evaporation: $MgSO_4$ 31–33%, $MgCl_2$ 2–4, NaCl 18–20, KCl 19–21. Not a mineral.

W. F. F.

Potarite

L. J. SPENCER: *Mineral. Mag.*, **21**, No. 117, p. 235 (1927). The palladium amalgam from the Potara River (*Am. Mineral.*, **10**, 33, 1925) has been distributed by Sir J. B. Harrison under the name potarite. Spencer mentions this name in his biographical notice of Sir J. B. Harrison. W. F. F.

Muntenite

L. J. SPENCER: *Ibid.* p. 247.

Spencer notes the name muntenite, in honor of George Murgoci (George Munteanu), given to a variety of Roumanian amber, but no description of this seems to be available. W. F. F

Unnamed Mineral

H. R. ADAM: A note on a new Palladium Mineral from the Potgietersrust Platinum Fields. *Jour. Chem. Met. Min. Soc. South Africa*, **27**, 249—250 (1927).

CHEMICAL PROPERTIES: An antimonide of palladium, Pd_3Sb. Analysis: Pd 70.4, Sb 26.0, Insol. 1.4, Fe_2O_3 0.9. Unattacked by nitric and sulphuric acids but easily soluble in acqua regia. Platinum is absent or present only in very small amounts.

PHYSICAL PROPERTIES: Color silvery white to darker steel gray. Sp. Gr. 9.5.

OCCURRENCE: Found at the farm Tweefontein of the Potgietersrust Platinum Company, associated with sperrylite. The sperrylite occurs in sheer zones traversing the banded iron stone of the Pretoria Series. Included in these zones are eyes of pegmatite. The new mineral was found as small crystals closely associated with the pegmatite. W. F. F.

Collinsite

EUGENE POITEVIN: A new Canadian occurrence of phosphorite from near François Lake, British Columbia. *Canada Dept. Mines, Bull.* **46**, 5–9 (1927).

NAME: In honor of *W. H. Collins*, Director of the Geological Survey, Canada.

CHEMICAL PROPERTIES: A hydrated phosphate of lime, magnesia and iron oxide. Formula: $2CaO\,(Mg, Fe)O \cdot P_2O_5 \cdot 2\frac{1}{2}H_2O$. Analysis (by E. A. Thompson) CaO.32.18, FeO 6.86, MgO 6.34, MnO tr., Fe_2O_3 0.80, Mn_2O_3 0.36, Al_2O_3 0.39, P_2O_5 39.83, F 0.27, CO_2 0.23, H_2O- 0.15, H_2O+ 12.28, C 0.18, SiO_2 0.10. Sum $(-0=F, 0.11)$ 99.86. Easily soluble in acids. Fusible at 3 to brownish slag.

CRYSTALLOGRAPHIC PROPERTIES: Triclinic with four cleavages with the following angles $C_o \wedge C_1 = 88°40'$, $C_1 \wedge C_2 = 108°00'$, $C_2 \wedge C_3 = 111°00'$, $C_1 \wedge C_3 = 131°00'$.

PHYSICAL AND OPTICAL PROPERTIES: Color light brown. Luster silky. Optically positive. $2V = 80°$. $\alpha = 1.632$, $\beta = 1.642$, $\gamma = 1.657$. Birefringence 0.025. $\beta \wedge C_1 = 150°$, $\beta \wedge C_2 = 66°$, $\beta \wedge C_3 = 44°$. Sp. Gr. 2.95. Hd. $= 3 - 3.5$.

Occurrence: Found in abundance on the north side of François Lake, British Columbia, as nodules together with quercyite in a small irregular vein 4–12 inches wide associated with asphalt and brecciated andesite.

Discussion: Collinsite is a member of the roselite group and is the magnesia analogue of messelite.

W. F. F.

ADDITIONAL DATA

Tinzenite

J. Jakob: Die Tinzen—varietäten aus dem Val d'Err. (Graubünden). (The Tinzenite varieties of Val d'Err, Graubünden) *Schweiz. Min. Petr. Mitt*; **6**, 200–202 (1926).

The color varies from lemon yellow to orange red. Two new analyses are given:

	Orange yellow	Orange red
SiO_2	41.22	41.08
TiO_2	0.11	tr.
Al_2O_3	17.41	16.55
Fe_2O_3	1.69	2.32
Mn_2O_3	22.18	22.50
MgO	0.69	0.66
CaO	14.19	15.01
Na_2O	0.48	0.12
K_2O	0.42	0.66
H_2O+	1.33	1.07
H_2O-	0.08	0.06
	99.80	100.03

Mn''' gives minerals of light tones—yellows. Mn'' gives red browns to copper red. In the yellow tinzenites Mn''' is present alone. In the orange ones a small amount of Mn'' is present.

W. F. F.

Truscottite

J. A. Grutterink: Truscottiet. *Verh. Geol. Mijn. Genoot. Nederland. Geol., Ser.* **8**, pp. 197–200 (1925).

Original Description: P. Hövig: *Jaarb. Mijn. Nederland*, **41**, (1912).

Chemical Properties: A hydrous silicate of lime and magnesia. 2(Ca, Mg)O. $3SiO_2$. 1.3 H_2O (if "essential" water is considered) or 2(Ca, Mg)O. 3 SiO_2. 3 H_2O (if all the water is included). Analysis (on material of demonstrated purity; average of two): SiO_2 57.83, CaO 26.43, MgO 5.33, FeO 0.08, MnO 0.25, Al_2O_3 0.95, K_2O 0.73, Na_2O 0.78, H_2O (+) 4.10, H_2O (−) 3.41; Sum 99.89.

Physical and Optical Properties: Color white, luster pearly on cleavage. Birefringence weak. Extinction parallel. Elongation negative. $n = 1.560$.

Occurrence: From the Lelong Donok gold mine, Benkoelen, Sumatra, as white spheroidal aggregates.

Discussion: Related to gyrolite but the name truscottite provisionally retained since it shows some minor physical differences from gyrolite.

W. F. F.